

Overview of ERA Ultra High Bypass Propulsor Technology Development

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ERA Ultra High Bypass Technology Research

➤ ***Isolated UHB Testing Subelement comprised of four ERA funded activities:***

1. Collaborate with P&W to design, fabricate and test a second generation of Geared Turbofan
2. Design, fabricate and test advanced Over the Rotor acoustic treatment and acoustically treated Soft Vanes
3. Develop a Shape Memory Alloy Variable Area Nozzle concept and demonstrate prototype
4. Refurbish and update the GRC Ultra High Bypass Drive Rig

➤ ***Research plan leads to high TRL demonstrations of propulsor technology that will enable reductions in both fuel burn and noise***

1. NASA/P&W collaboration to develop GTF Gen 2

- P&W will design and fabricate a 22” fan model of their second generation Geared Turbofan under current GRC RTAPS task order contract; GRC will provide design support and wind tunnel test facility
- Testing will include fan performance, flowfield diagnostics, and far field acoustics, including effect of angle of attack
- GRC will also test a 22” scale model of the GTF Gen 1 fan blade design known as Aero 2 to compare with PW1000G engine data (Gen 1 demo engine using Aero 2 fan)
 - Goal is to understand how successfully full scale performance can be modeled in sub scale tests, especially acoustics
- Test is scheduled to begin in the GRC 9’x15’ Low Speed Wind Tunnel in late October 2011

2. Advanced Noise Reduction Technology

Over the Rotor

- Develop and demonstrate a second generation of Over the Rotor noise reduction technology for UHB propulsion
 - Task being performed in partnership with Langley (Mike Jones) and with support of the Subsonic Fixed Wing Project
- Samples of candidate concepts are being mechanically designed and fabricated by GRC (ASRC); LaRC is conducting acoustic testing of samples
 - Initial sample test results show excellent absorption coefficients across a wide frequency range
- CFD aero performance predictions have been performed under contract by AP-Solutions (Dan Tweedt) to assess impact of potential designs on fan performance; performance results are also being used to guide OTR designs for sample evaluations

2. Advanced Noise Reduction Technology

Over the Rotor

- Current concepts propose discrete chambers behind perforated fan rubstrip instead of metal foam in open chamber; novel Rapid Prototype manufacturing process used to fabricate samples
- Fan rubstrip preliminary aero design includes geometry features to mitigate performance losses
- The Source Diagnostic Test R4 fan model will be used as noise source in testing; fan will be operated at lower speeds to simulate lower pressure ratio fan
- SDT R4 fan and new OTR treatment design will be tested in GRC W8 facility prior to wind tunnel test to insure minimal impact on aero performance
- Wind tunnel validation of new OTR design scheduled for in GRC 9'x15' LSWT in Spring 2012

2. Advanced Noise Reduction Technology

Soft Vanes

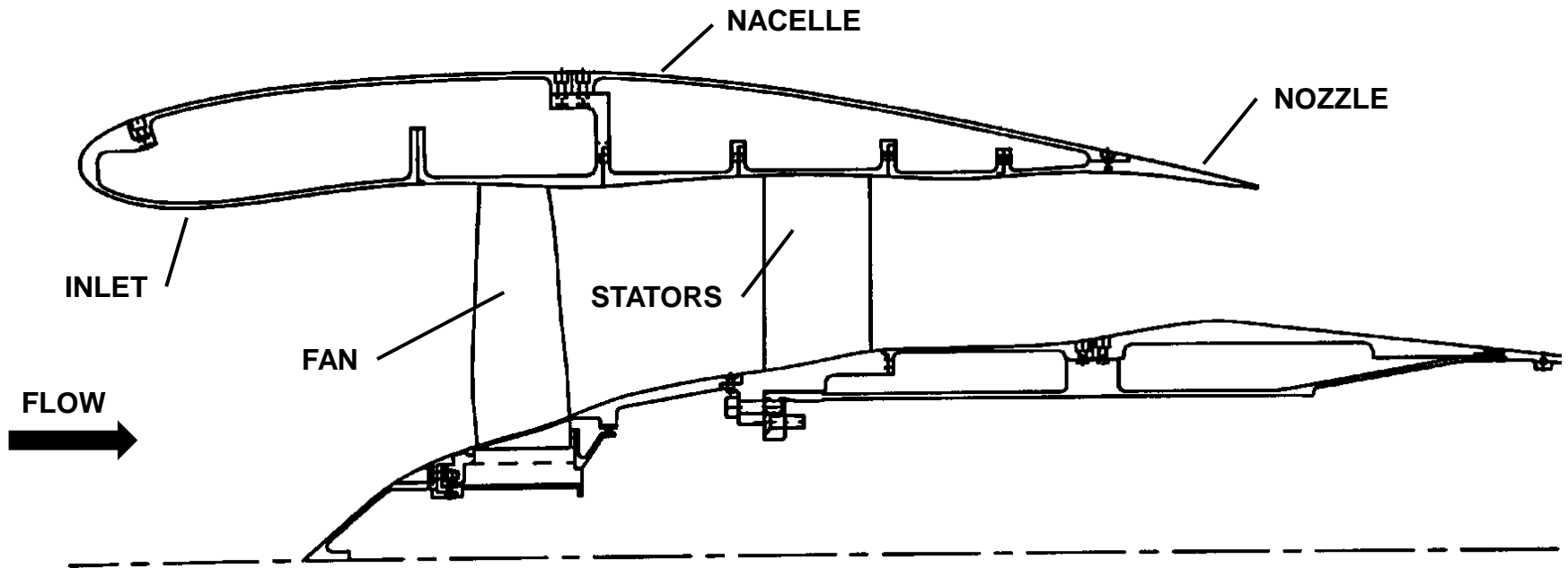
- Develop and demonstrate a second generation of Soft Vanes noise reduction technology for UHB propulsion
- New concept based on proposed second generation OTR acoustic designs of using discrete chambers inside the vane
 - Holes on vane surface allows acoustic waves to penetrate into chambers and local modification of unsteady pressure noise sources
- SV designed will identically replace SDT Low Count stators (26 vanes, cut-on) and have identical vane geometry with same aero performance
- 3D acoustic prediction codes used to optimize location and extent of porous surface openings leading to chambers

2. Advanced Noise Reduction Technology

Soft Vanes

- LaRC (Mike Jones and Brian Howerton) is performing acoustic design using new design tool; GRC is responsible for mechanical design and fabrication
- State-of-the-art Rapid Prototyping manufacturing technology will be used to fabricate vanes, allowing construction of unique chamber designs within structural metal vanes
- SV validation testing using SDT fan model planned for GRC 9'x15' wind tunnel in Spring 2012, concurrent with OTR test

Source Diagnostic Test fan model with 22 blade R4 fan and 26 stators (acoustically cut-on)

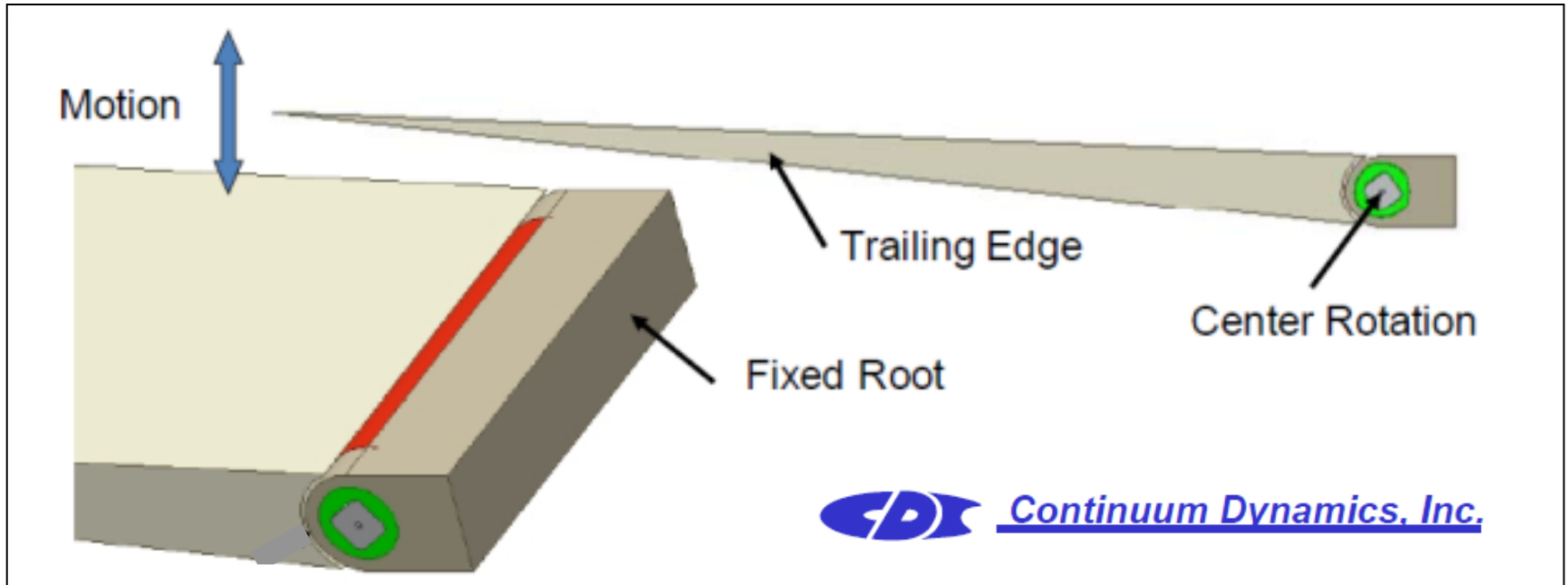


3. Shape Memory Alloy Variable Area Nozzle

➤ Objectives

- Develop SMA technology suitable for use in a deflected flap type VAN concept for a 22" fan model
 - Construct realistic scale model prototype to demonstrate SMA VAN concept
- #### ➤ SMA technology being developed through SBIR Phase 3 award (Continuum Dynamics); contractor is developing the SMA technology and application design using SMA
- #### ➤ GRC is also working collaboratively with the contractor to develop materials suitable for SMA application, in both hot and cold environments
- #### ➤ Progress to date indicates a SMA concept is viable and can be employed into VAN concept, and potentially within current nozzle mold lines

Variable Area Nozzle Concept using Shape Memory Alloy



4. UHB Drive Rig Upgrade

- Advanced LPR and UHBR fan designs require more complex and more sensitive health monitoring instrumentation during testing; high speed aero performance test techniques require faster data acquisition methods
- Upgrades include:
 - High fidelity digital data system with local signal conditioning (high s/n ratio) and higher channel count for additional instrumentation (more fan strain gages); much more robust, adaptable design
 - On board, noise free, telemetry-based data transmission system enables high speed data transfer, replacing slow, noisy slip ring system
 - Six component dynamic force balance for measuring fan performance in highly distorted inflow conditions, such as 1P loads
 - New muffler to reduce drive rig turbine self noise

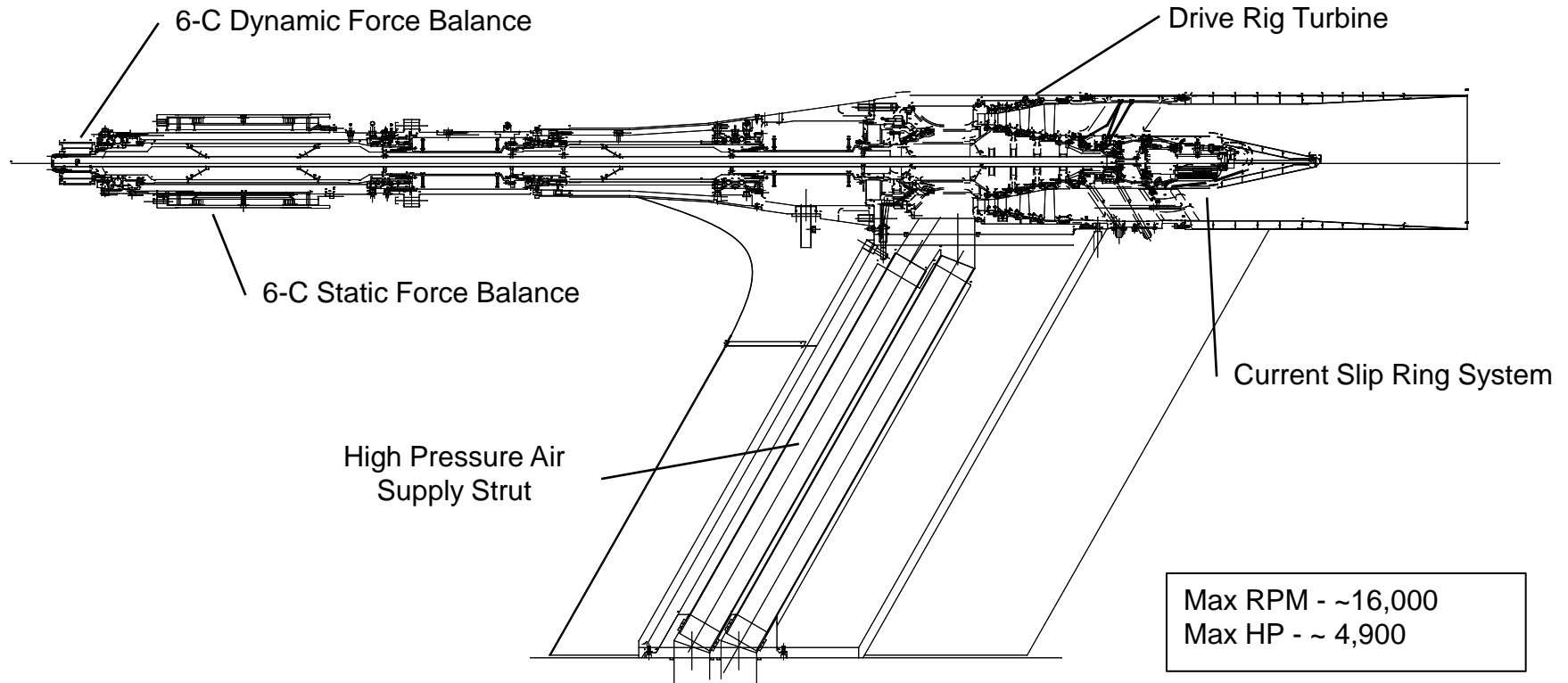
Proposed Additional UHB Technology Testing

- Additional funding is being sought for demonstrating advanced UHB technologies at TRL 4, including:
 - 22” SMA VAN to fit SDT fan model, replacing existing fixed area nozzles that are used to vary fan operating line
 - Advanced lightweight, variable impedance liner
 - In-Duct Phased Array acoustic diagnostic technique
- Testing would be conducted in conjunction with UHB OTR/SV test entry and SDT fan model in the GRC 9’x15’ wind tunnel in Spring 2012 to take advantage of test model opportunity

Ultra High Bypass Drive Rig in GRC 9'x15' Low Speed Wind Tunnel



NASA Glenn Ultra High Bypass Drive Rig



Force Balance Capabilities

| | <u>Dynamic</u> | <u>Static</u> |
|-----------------------|----------------|---------------|
| Axial Force (lbf) | 2,000 | 2,000 |
| Normal Force (lbf) | 1,000 | 1,600 |
| Side Force (lbf) | 1,000 | 1,600 |
| Roll Moment (in-lbf) | 18,000 | 18,540 |
| Pitch Moment (in-lbf) | 2,000 | 55,200 |
| Yaw Moment (in-lbf) | 2,000 | 55,200 |

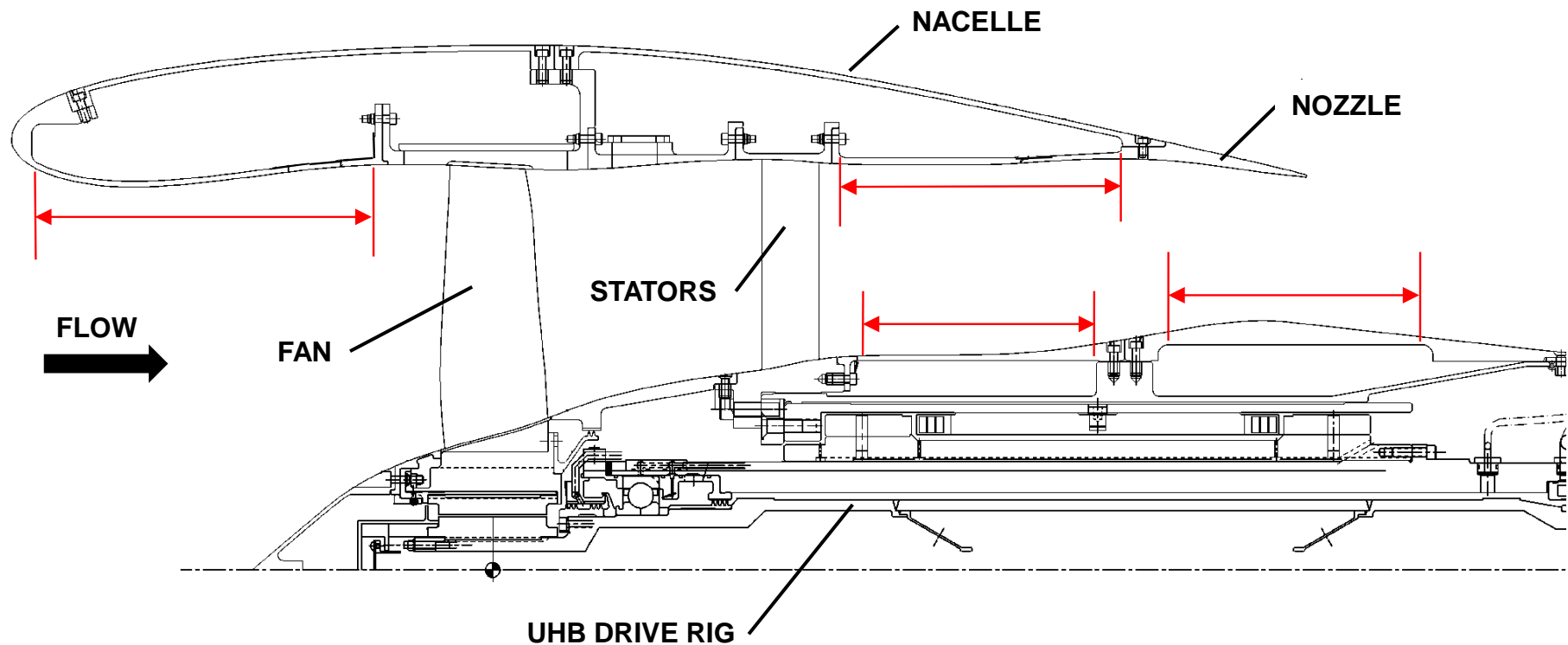
SMA VAN

- VAN is required for UHB engine cycles in order to vary fan operating line at low speeds to prevent flutter and stall
 - Also allows optimal operation of fan to achieve peak performance and minimum fuel burn at all conditions
- Currently, VAN technology not considered feasible for UHB propulsion with BPR above 15
 - Large nozzles and large nozzle area changes required make currently VAN technologies too heavy or have actuation range limitations
- Current SMA based VAN approach being studied under SBIR contract will allow implementation of VAN design for fans with $BPR > 15$
- GRC would design and fabricate SMA VAN based on SBIR results, in collaboration with Continuum Dynamics

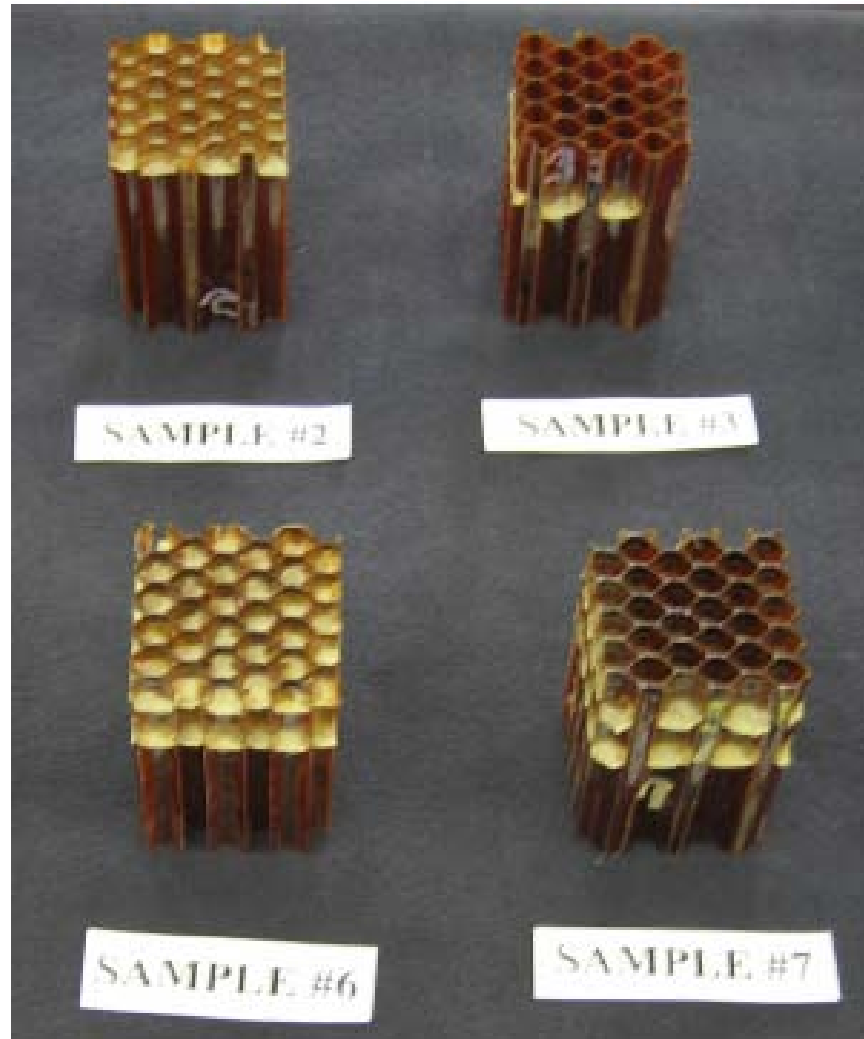
Advanced Lightweight, Variable Impedance Liner

- Advanced liner technology is critical for UHB applications with advanced nacelles, which may have less much area available for liner application
- Advanced liner technology being developed by LaRC in collaboration with Hexcel
 - Advanced liner will provide noise reduction over a significantly wider frequency range, and potentially less volume
 - New manufacturing technology allows liner to be optimally designed for maximum noise reduction
 - Phenolic resin chambers and soft septum material are lighter than conventional liners
- Currently, LaRC is designing liner for SDT R4 fan model; Hexcel will manufacture liner to LaRC specs for wind tunnel testing; GRC would design and fabricate fan model hardware to accept liners and conduct test

Potential locations for advanced liners in SDT fan model with 54 stators (cut-off acoustically)



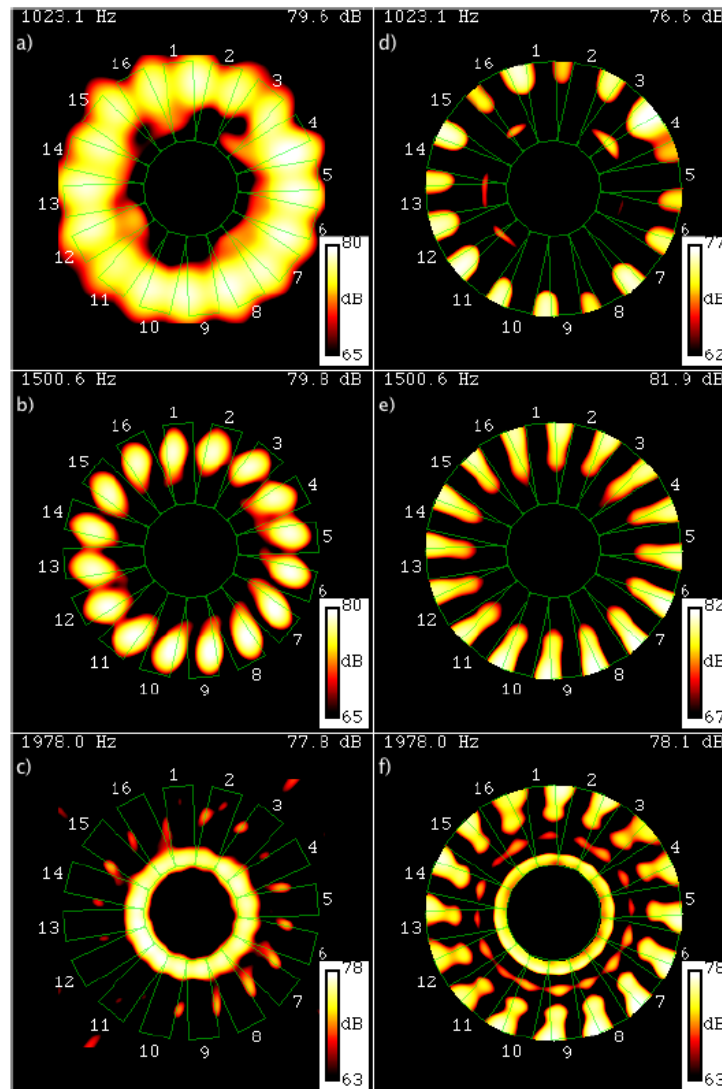
Examples of Hexcel SDOF and DDOF liners made with phenolic cells and soft septums



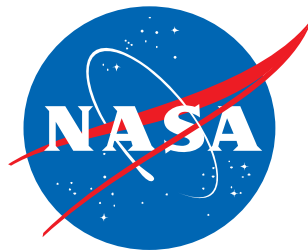
In-Duct Phased Array

- Develop application for use in SDT R4 fan model to image fan and stators in highly distorted inflow conditions to quantify impact on noise sources
 - Technology has been demonstrated at lower TRL in ANCF; additional testing planned in ANCF with higher fidelity system
 - Results show individual noise sources on the fan successfully imaged
- Currently, array configuration is being designed for SDT fan model application by Optinav, developer of acoustic imaging technique
- GRC would procure array system components, mechanically design and fabricate fan model hardware, and conduct test
- In addition to current SDT fan test, there is possible application for upcoming ERA/SFW sponsored Embedded Fan Test in late 2012, to assess acoustic noise sources of UHB fan operating in highly distorted flow produced by ingesting aircraft boundary layer

In-Duct Phased Array results from ANCF test



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Overview of ERA Ultra High Bypass Propulsor Technology Development

Summary

A review of the current research being conducted under the ERA Ultra High Bypass (UHB) Testing subelement is presented. The four existing tasks under the subelement, a description of each task, and the current status of each are given. The four tasks are:

1. Collaborate with P&W to design, fabricate and test a second generation of Geared Turbofan
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Following the current task updates, an overview of three proposed additional tasks to support the existing tasks is presented. The additional tasks would allow noise reduction and noise diagnostic testing technologies to be demonstrated at TRL 4 as part of existing planned fan model testing in the NASA Glenn 9'x15' Low Speed Wind Tunnel under the ERA UHB Testing subelement.